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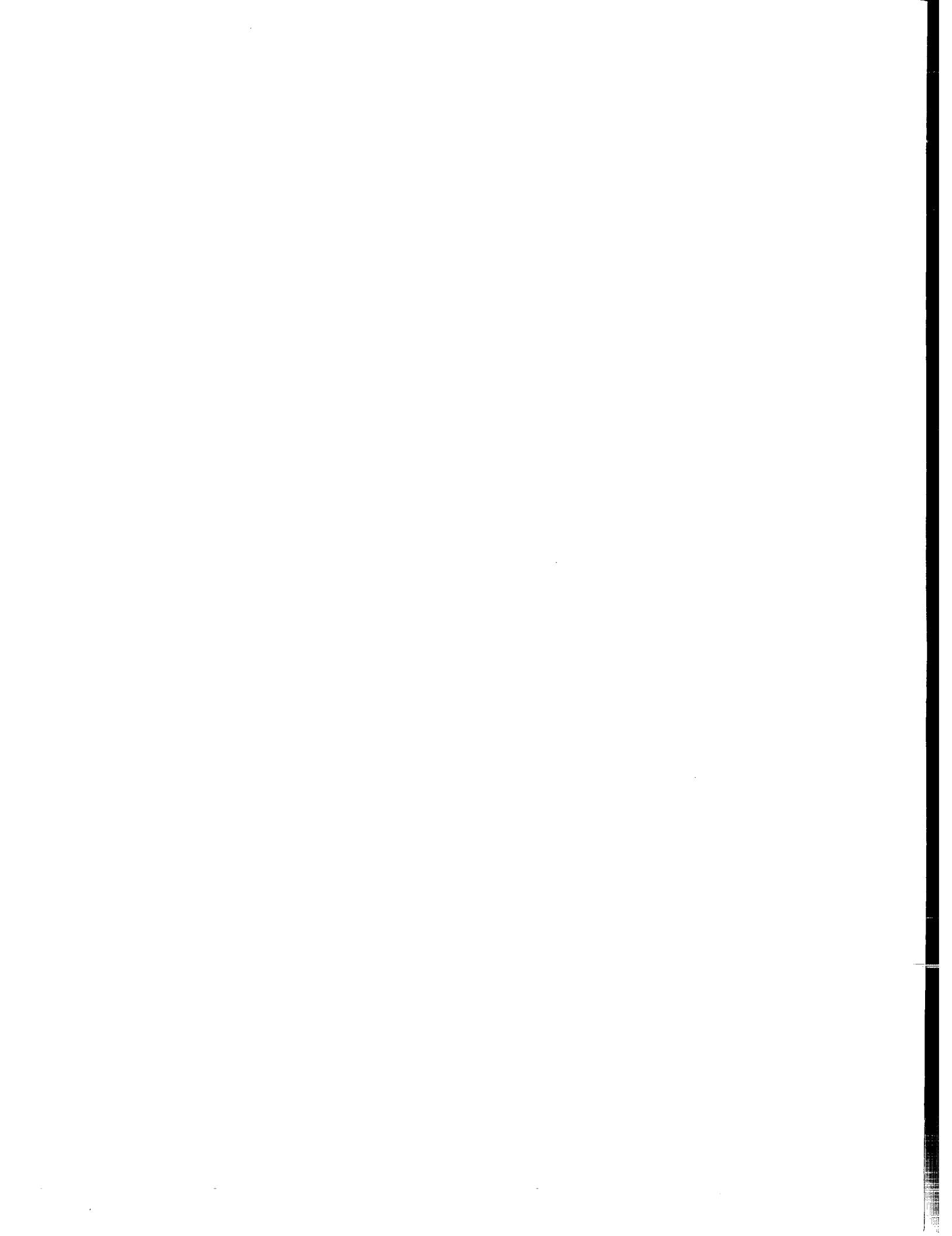
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Der Präsident des Europäischen Patentamts;
im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Cutting tool and method for cutting material

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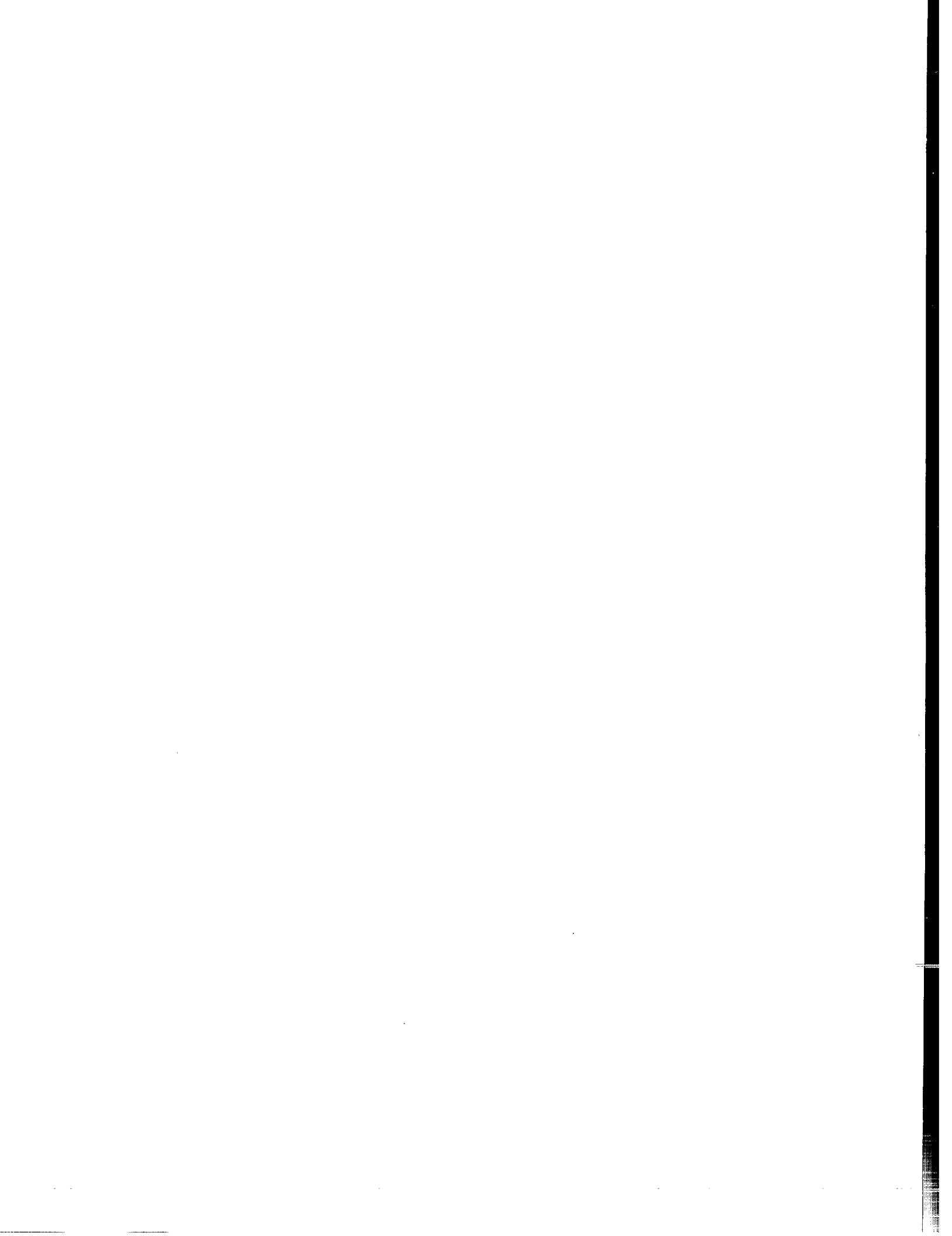
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As requested, the entries pertaining to the applicant of the above-men-
tioned European patent application/to the proprietor of the above-men-
tioned European patent have been amended to the following:

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The registration of the changes has taken effect on 11.03.05...



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Cutting tool and method for cutting material

The invention concerns a tool for cutting materials in accordance with the 5 preamble of claim 1. The known cutting tool has the disadvantage that when cutting a cutting section that is asymmetrical the cutting tool tends to drift sideways in a direction perpendicular to the rotation axis. This leads to inaccuracies and requires that material be machined at a lower cutting speed and/or feed rate.

In order to overcome this disadvantage the tool is designed in accordance with 10 the characterizing part of claim 1. During machining the inner cutting edges will generate stabilizing forces on the cutting tool that prevent sideways drifting so that more accurate machining at a higher cutting speed and/or feed rate can be achieved.

In a preferred embodiment of the present invention the tool is according to 15 claim 2. In this way the rotating cutting tool is further stabilized during cutting.

16 In another preferred embodiment of the present invention the tool is according to claim 3. In this way the forces on the cutting edges are more constant.

In still another preferred embodiment of the present invention the tool is according to claim 4. This will ensure that the inner cutting edges generate sufficient 20 stabilizing force on the body.

25 In another preferred embodiment of the present invention the tool is according to claim 5. This facilitates sharpening of the cutting edges, for instance by grinding.

In a further preferred embodiment of the present invention the tool is according to claim 6. By giving the first cone and the second cone approximately the same top angle the chips cut from the material will have a similar shape, which makes handling easier.

30 In still a further preferred embodiment of the present invention the tool is according to claim 7. The support planes support the body for preventing sideways movement, thereby further stabilizing the cutting tool during machining.

In another preferred embodiment of the present invention the tool is according to claim 8. This makes sharpening of the cutting edges easier.

35 In still another preferred embodiment of the present invention the tool is according to claim 9. In this way the supporting planes and the cutting edges are at the same location so that slots for chip removal can be made easier.

In a further preferred embodiment of the present invention the tool is according to claim 10. This makes it possible to have sufficient cutting edges cutting at one time 35 while the cutting teeth remain sufficiently strong to withstand the cutting forces.

In still a further preferred embodiment of the present invention the tool is according to claim 11. This makes it possible to machine deep slots and openings with the cutting tool.

The invention also concerns a method according to the preamble of claim 12.

5 The disadvantage of this method is that during cutting the cutting tool may drift sideways due to variable forces on the body. In order to overcome this disadvantage the method is according to the characterizing part of claim 12. This ensures that the inner cutting edges and the outer cutting edges are subject to the same cutting forces and so stabilize the tool during cutting.

10 The invention also concerns a method according to the preamble of claim 13. The disadvantage of this method is that during cutting the cutting tool may drift due to variable forces on the body. In order to overcome this disadvantage the method is according to the characterizing part of claim 13. This ensures that the changing forces on the inner cutting edges when starting to cut the material or ending to cut the material are 15 stabilized by at least one other inner cutting edge engaged in cutting the material.

The invention is further explained and illustrated with reference to the following embodiments and accompanying drawings which, however, should not be construed as limiting the invention in any respect.

In the drawings:

20 Figure 1 is a side view of a first embodiment of a cutting tool;

Figure 2 is a side view of the cutting body of the cutting tool of Figure 1 in more detail;

Figure 3 is a bottom view of the cutting body of the cutting tool of Figure 1;

25 Figure 4 is a side view of the cutting edges of the cutting tool of Figure 1 in more detail;

Figure 5 is a side view similar to the view of Figure 4 of the cutting edges of a second embodiment of a cutting tool;

Figure 6 is a bottom view of the cutting edges of the cutting tool of Figure 5;

30 Figure 7 is a schematic view of the sickle shaped area cut by the cutting tool of Figure 1 when machining with a step-distance of 0.2 of the cutting tool diameter;

Figure 8 is a schematic view of the sickle shaped area cut by the cutting tool of Figure 1 when machining with a step-distance of 0.3 of the cutting tool diameter; and

Figure 9 is a schematic view of the sickle shaped area cut by the cutting tool of 35 Figure 1 when machining with a step-distance of 0.4 of the cutting tool diameter.

Figures 1, 2 and 3 show a cutting tool 1 with a clamping surface 3 clamped in a tool clamp 2. The tool clamp 2 is part of a machine tool which is numerical or conventional controlled and can position and move the cutting tool towards the to be machined part. During use the cutting tool 1 is rotated around a rotation axis L with a 5 rotation speed and fed with a feed rate A in a feed direction into material to be cut. The cutting tool 1 is provided with cutting teeth 5 which are connected by a shank 4 with the clamping surface 3. The number of cutting teeth may vary and is usually in the range of two to five, preferably four. The cutting teeth 5 have a cutting diameter D and a cutting height H. At the side away from the shank 4, the underside, the cutting teeth 5 have 10 cutting edges 10 for cutting the material. Due to the fact that the cutting edges 10 are at the end of the cutting tool 1 this type of tool is also known as an end mill. At the circumference the cutting teeth 5 have support faces 8, which during machining a part support the cutting tool 1 against the cylindrical surface that remains of the part after machining. The cutting tool 1 as depicted has four cutting teeth 5, the cutting edges 10 are 15 at a distance L from the tool clamp 2 and this distance is at least four times the diameter D, so that also narrow and deep slots can be machined.

The cutting teeth 5 are generated by machining flutes 11 in a cylindrical body, for instance by grinding. The outer dimensions of the cylindrical body are identical to the final outer dimensions of the support planes 8 and the cutting edges 10. Machining of the 20 flutes 11 creates the cutting faces 9 which intersect with the outer circumference of the cylindrical body so creating the cutting edge 10 at the underside and a sharp edge along the support face 8. In the shown embodiment there are four flutes 11 but the number may vary, usually in the range from two to about five. In this embodiment cutting faces 9 are in a plane that includes the rotation axis L but this is not essential.

25 At the underside of the cutting tool 1 approximately perpendicular to each cutting face 9 the cutting teeth 5 have a first relief face 6 along the cutting edge 10 so that during use the underside of the cutting tooth 5 does not interfere with the material to be cut. The first relief face 6 and the cutting face 9 have such angles relative each other and relative to the direction of movement of the material due to the rotation of the cutting tool 1 30 that the cutting conditions for that material and the further cutting conditions are optimized in a known way.

The cutting tooth 5 has sufficient thickness for taking up the cutting forces generated on the cutting face 9 during use. In order that the cutting tooth 5 remains free on the underside of cutting tool 1 from the material to be machined, there is machined at 35 the underside of the cutting tooth 5 a second relief face 7 which makes sure that the underside of the cutting tooth 5 remains inside the body of revolution generated by the

cutting edge 10. The second relief face 7 is continued upward along the length of the support face 8 so that from the outer circumference of the cylindrical body there remains only a narrow band as the support face 8, which reduces the friction against the machined material.

5 In Figure 4 the cutting edge 10 is shown in more detail. The cutting edge 10 comprises an outer cutting edge 12, which is approximately a straight line making an angle α_1 with the direction of the rotation axis L and which is limited at the outside diameter by the support face 8 and at the inside by a lower limit 13, which is the lowest point of the cutting tooth 5. The angle α_1 generally has a value of approximately 30
10 degrees but may also approach zero so that the surface of revolution generated by the rotating outer cutting edge 12 is a cone or a flat plane. Inside the lower limit 13 the cutting edge 10 comprises an inner cutting edge 14 which is an approximately straight line making an angle α_2 with the direction of the rotation axis L. The angle α_2 generally has a value of approximately 30 degree so that the surface of revolution generated by the
15 rotating inner cutting edge 14 is a cone whereby the material to be machined presses against the first relief face 6 in the direction of the outside diameter of the cutting tool 1.

As the forces pressing on the relief face 6 of the cutting tooth 5 on both sides of the lower limit 13 have opposite directions, the resulting force on the cutting tooth 5 in the plane perpendicular to the rotation axis L is reduced, so that the tool is more stable
20 during cutting. In the case where α_1 is approximately zero the force generated on the inner cutting edge 14 is compensated by the forces on the support face 8.

Figures 5 and 6 show a second embodiment of a cutting tool, wherein the inner cutting edge 14 and the outer cutting edge 12 both end in a lower limit 13 and have a shape different from a straight line. Due to the fact that the lower limit 13 has a distance
25 from the rotation axis L and there is an inner cutting edge 14 during cutting the tool is more stable. In this embodiment a canal 15 is shown for providing cooling fluid. Alternatively, cooling fluid may be supplied externally or through the shaft

In addition to the embodiments shown here the design of the cutting edges 10 can be used in end mills of different shape. For instance the number of flutes 11 can be
30 changed, the cutting face 9 can be helical and/or the cutting height H can be reduced or increased to ten or twenty times the cutting diameter D. The cutting tool 1 can be made from HSS or from carbide and, if desired, it can be coated with a TiN coating or any other suitable coating. Instead of making the cutting tool 1 from a full body as shown here carbide inserts can be used for the cutting edges 10.

35 In Figure 7 the area is shown of the material that is removed during machining with the cutting tool 1. The cutting tool 1 has a diameter D and an axis of rotation L. In a

first pass the cutting tool 1 is with its axis of rotation L in a rotation center M_1 and while rotating with a rotation speed that is dependent on the maximal allowable speed at the circumference of the cutting tool 1 inserted with a feed rate A in the direction of the rotation axis L and it removes material with a cutting radius R_T , which equals 0.5 D. After 5 cutting the first pass the cutting tool 1 is retracted by the machine tool and is moved a step distance S_D , so that the axis of rotation L is now in a rotation center M_2 and the cutting tool 1 is inserted in the direction of the rotation axis L. As a result a sickle shaped area of material is removed. In Figure 7 the step distance S_D is 0.2 D or 0.4 R_T . It can be seen that the material is cut in a narrow sickle near the outer circumference of the cutting tool 1, so 10 that the cutting speed is near the maximum allowable cutting speed at the circumference for the larger part of the sickle shaped area. As the cutting speed is also fairly high near the inside diameter of the sickle shaped area the feed rate A can be set at a high value so that the cutting capacity of the cutting tool 1 using this step distance S_D is high.

By increasing the step distance S_D as shown in Figures 8 and 9 the sickle 15 shaped area that is machined in one pass will be increased. This results in less loss of time required for repositioning the cutting tool 1 between a first pass and a next pass. However with increasing step distance S_D the feed rate A has to be reduced as the cutting conditions near the axis of rotation L deteriorate. For this reason the optimal cutting conditions and the optimal step distance S_D will depend on the material to be cut, and on 20 the material of the cutting tool 1. It has been found that in general good cutting results and cutting capacity are obtained if the step distance S_D is approximately 0.3 D as shown in Figure 8.

The stability of cutting with the cutting tool 1 depends on the design of the cutting edge 10 and especially on the radius of the limit 13. The preferred solution for the 25 radius of the lower limit 13 of the cutting edge 10 is the radius whereby the volume machined by the inner cutting edges 14 from the sickle shaped area is equal to the volume of the sickle shaped area machined by the outer cutting edges 12. An approximation for the minimum value of this radius is given. In Figures 7, 8 and 9 a first radius R_1 is shown which is the minimum value of the radius of the lower limit 13 and also 30 a small radius R_S , which is the smallest radius that the cutting edge 10 cuts the sickle shaped area. The value of R_S is equal to the tool radius R_T minus the step distance S_D . This first radius R_1 is calculated such that a ring with an inner radius equal to the small radius R_S and an outer radius equal to the first radius R_1 has the same surface as a ring with an inner radius equal to the first radius R_1 and an outer radius equal to the tool radius 35 R_T . It has been found that if the lower limit 13 of the cutting edge 10 at least equals the first

radius R_1 the cutting forces on the inner cutting edge 14 would stabilize the cutting tool 1 adequately.

In some circumstances stabilization is found if at least two inner cutting edges 14 are cutting the sickle shaped area. In the situation in which there are four cutting teeth 5 the lower limit 13 of the cutting edge 10 should be at least equal to a second radius R_2 . In situations where there are more cutting teeth 5, which is possible with larger diameters D, the second radius R_2 wherein there are at least two inner cutting edges 14 cutting the sickle shaped area can be made smaller. In such situations it is still preferred to have the radius of the lower limit 13 of the cutting edge 10 at least equal to the first radius.

Claims

1. Tool for cutting materials comprising a rotatable body with a rotation axis (L) and cutting edges (10) for cutting the material during movement of the body in a first direction parallel to the rotation axis characterised in that the cutting edges (10) comprise inner cutting edges (14) laying on a first surface of revolution which is in the first direction higher at a larger diameter and lower at a smaller diameter.

2. Tool according to claim 1 wherein at a diameter larger than the inner cutting edges (14) outer cutting edges (12) are laying on a second surface of revolution which is in the first direction lower at a larger diameter and higher at a smaller diameter.

3. Tool according to claim 1 or 2 wherein the first surface and the second surface intersect at a circle and the inner cutting edges (14) and the outer cutting edges (12) extend to this circle.

4. Tool according to claim 3 wherein the circle has a diameter of at least half of the maximum diameter of the outer cutting edges (12).

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5. Tool according to claim 1, 2, 3 or 4 wherein the first surface and/or the second surface are a cone.

6. Tool according to claim 5 wherein the top angle (α_2) of the cone of the first surface and the top angle (α_1) the cone of the second surface are approximately equal.

7. Tool according to any one of the previous claims wherein near the cutting edges (12) the rotatable body is provided on its outside circumference with support planes (8) laying in an approximately cylindrical surface being parallel to the rotation axis (L).

8. Tool according to any one of the previous claims wherein an inner cutting edge (14) and an outer cutting edge (12) form a cutting tooth (5).

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9. Tool according to claim 8 wherein the support planes (8) are located on the cutting teeth (5).

10. Tool according to claim 8 or 9 wherein the tool (1) has at least two 5 and preferably cutting teeth (5).

11. Tool according to one of the previous claims wherein the tool (1) is provided with a shank (4) for fastening the tool in a clamp (2) of a machine tool, the shank having a length such that the distance between the clamp and the cutting edges (10) is at 10 least four times the diameter (D) of the cutting edges.

12. Method for machining material using a tool according to one of the previous claims whereby the tool is rotated and in a first movement moved in the direction of its rotation axis (L) into the material, retracted, moved a step-distance (S_D) in a direction 15 perpendicular to its rotation axis and in a next movement moved in the direction of its rotation axis into the material thereby cutting a sickle shaped section of material characterised in that the step-distance (S_D) is such that the volume machined by the inner cutting edges (14) from the sickle shaped section of material is approximately equal to the volume machined by the outer cutting edges (12).

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13. Method for machining material using a tool according to one of the previous claims whereby the tool is rotated and in a first movement moved in the direction of its rotation axis (L) into the material, retracted, moved a step-distance (S_D) in a direction 25 perpendicular to its rotation axis and in a next movement moved in the direction of its rotation axis into the material thereby cutting a sickle shaped section of material characterised in that the step-distance (S_D) is such that at any moment at least two inner cutting edges (14) are cutting the sickle shaped section of material.

Abstract

Tool for cutting materials with a rotatable body having a rotation axis and cutting edges for cutting the material during movement of the body in a first direction parallel to the rotation axis. In order to stabilize the tool during cutting the cutting edges comprise inner cutting edges laying on a first surface of revolution which is in the first direction higher at a larger diameter and lower at a smaller diameter. The invention includes methods for using the tool.

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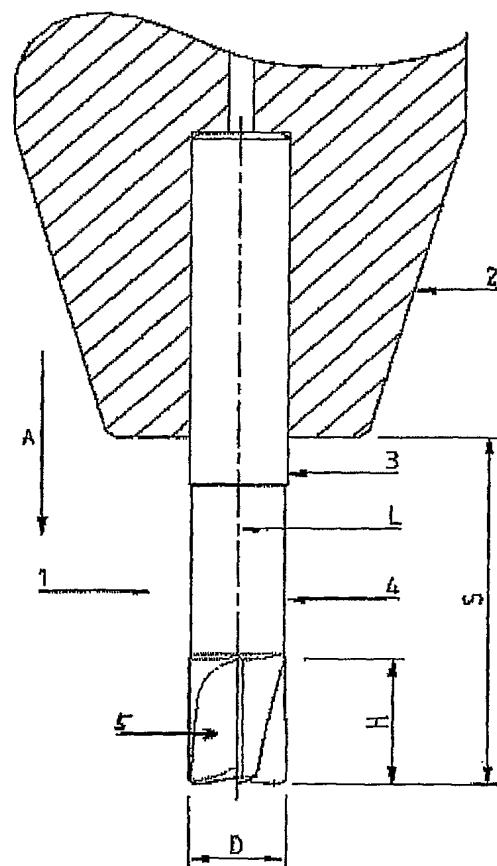


Fig. 1

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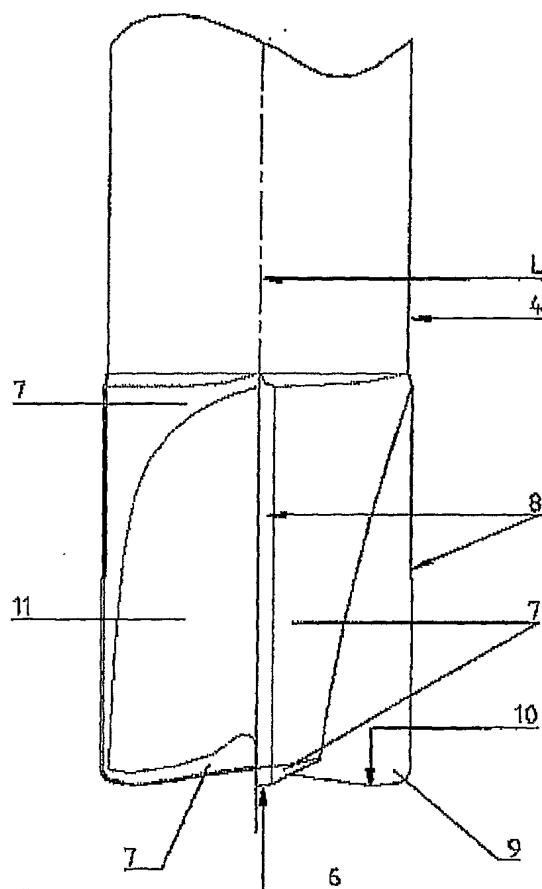


Fig. 2

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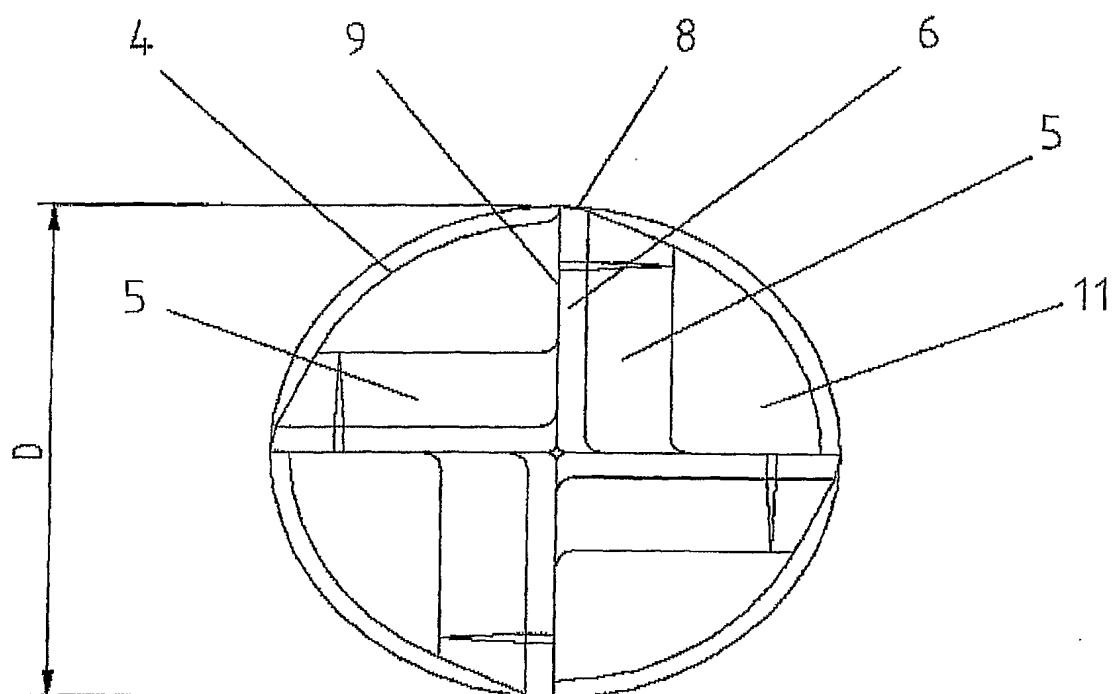


Fig. 3

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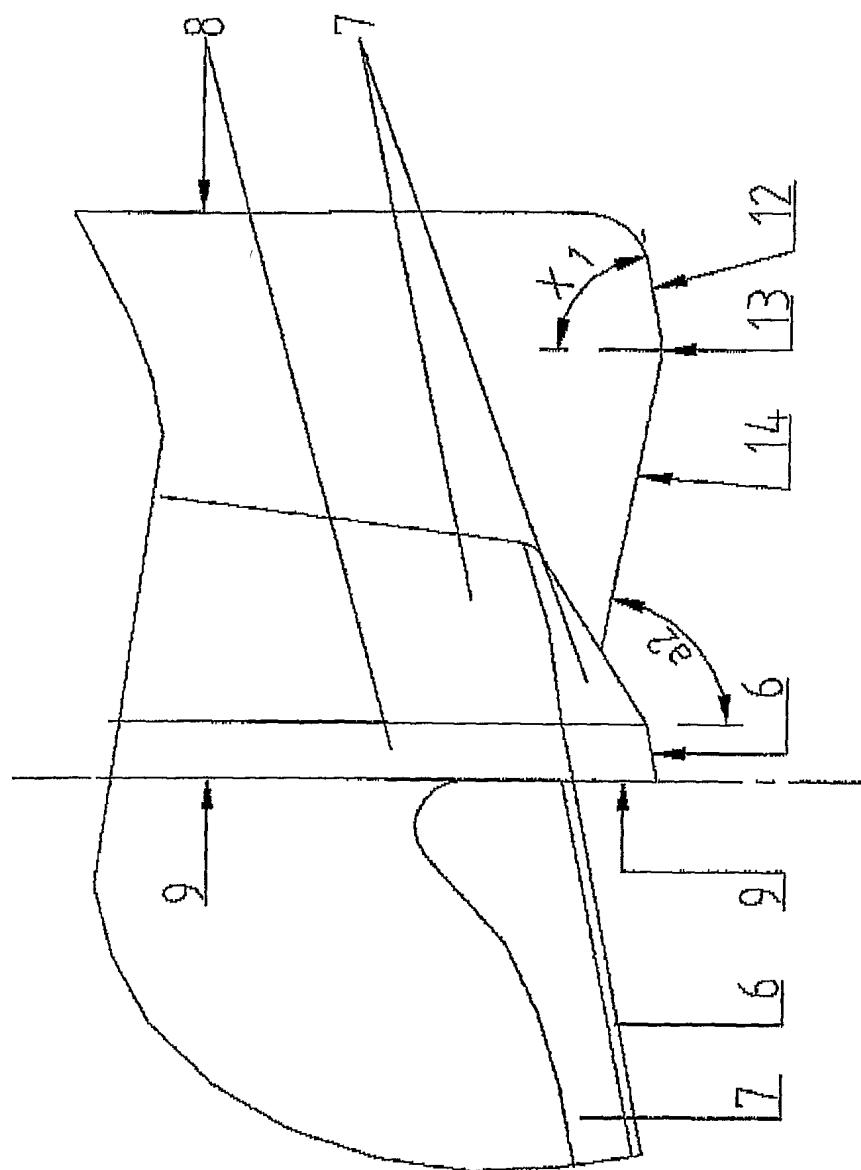


Fig. 4

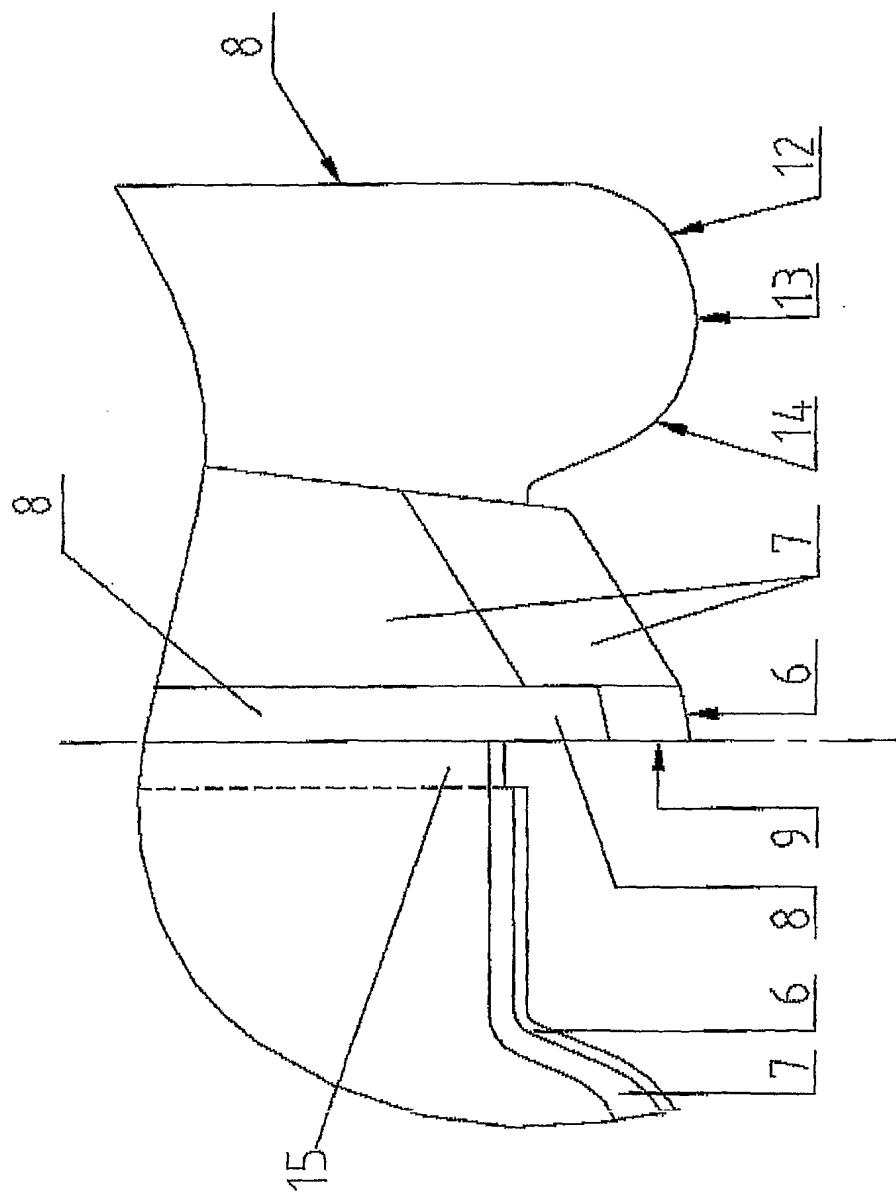


Fig. 5

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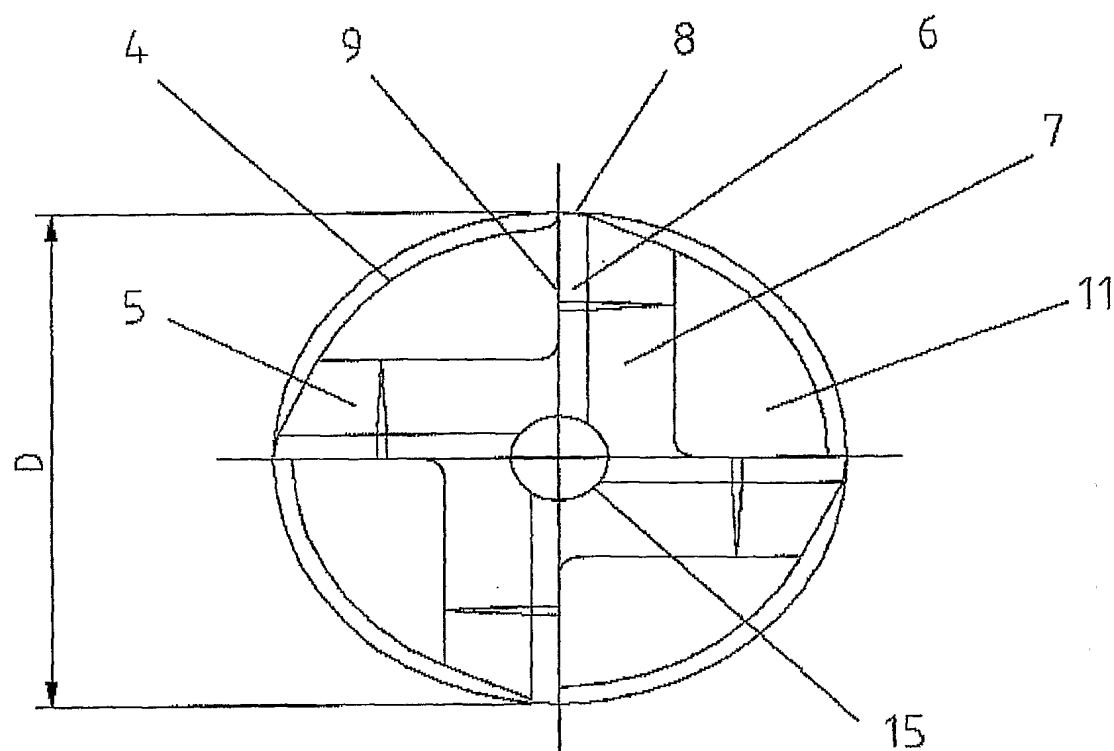


Fig. 6

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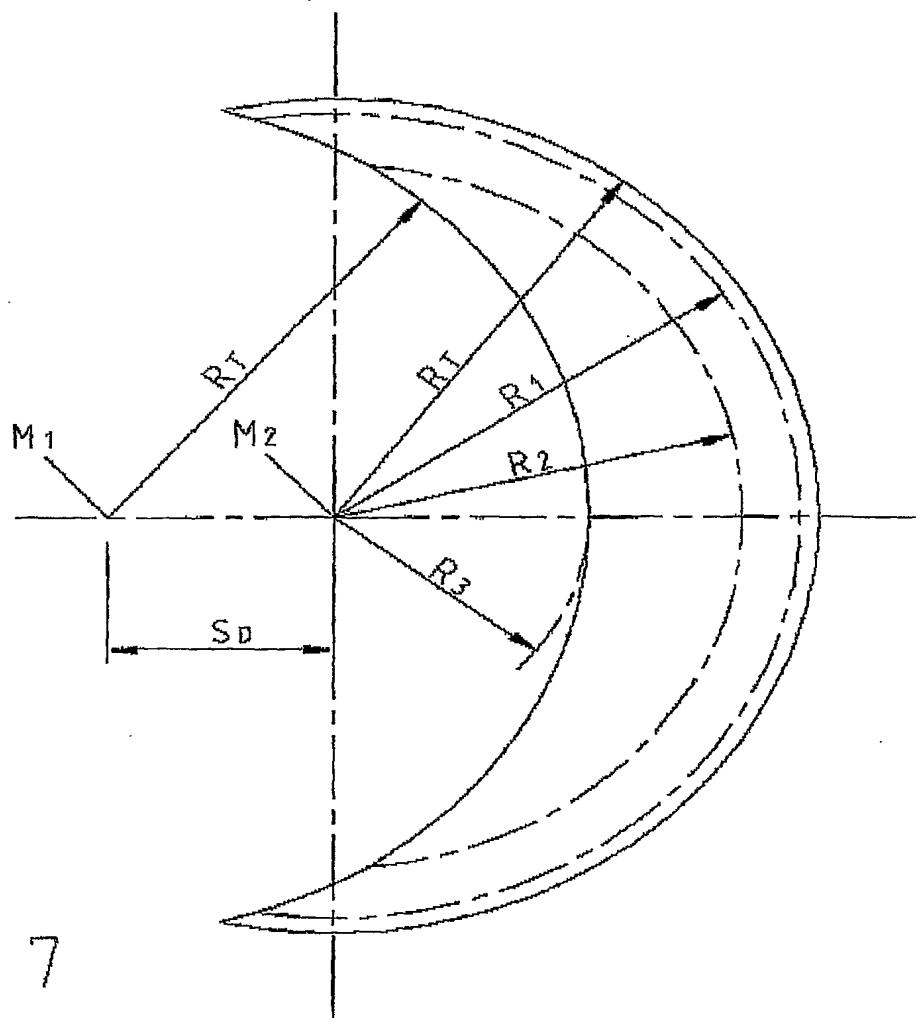


Fig. 7

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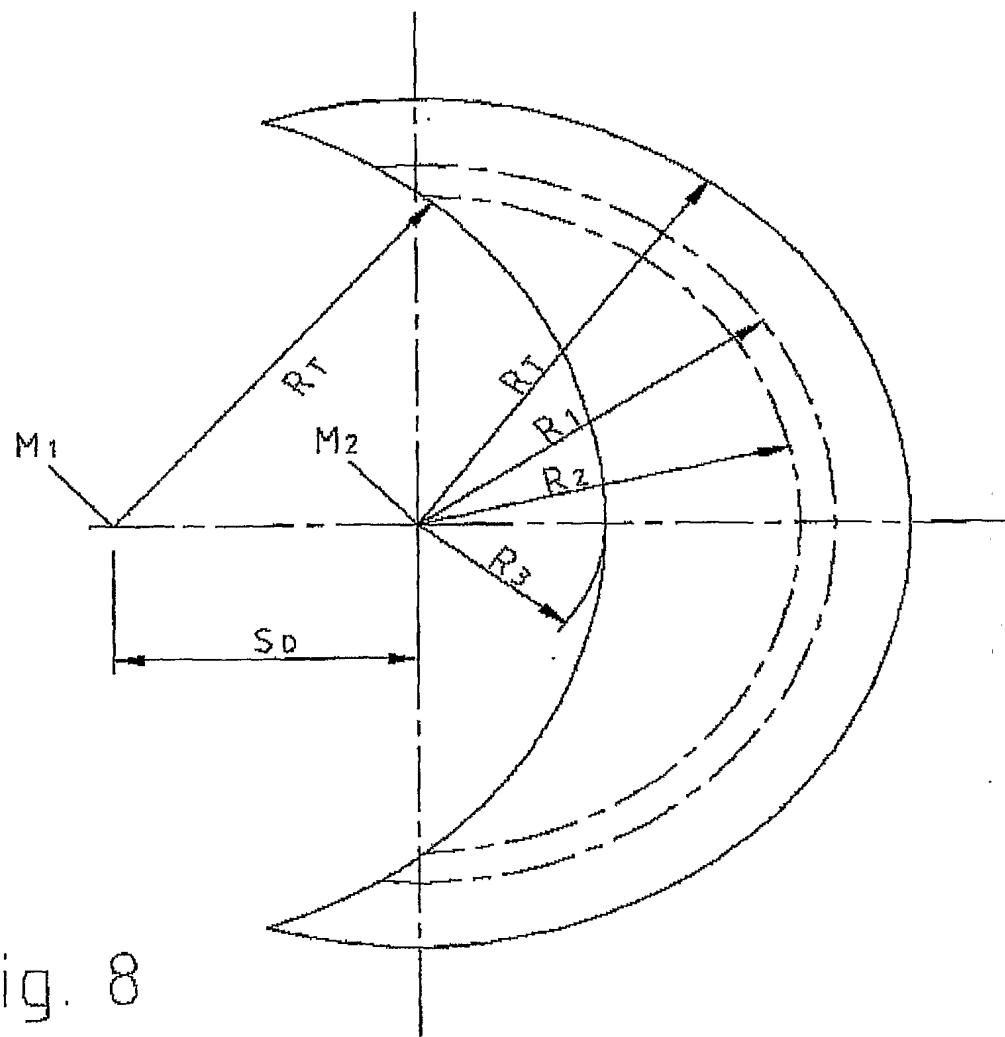


Fig. 8

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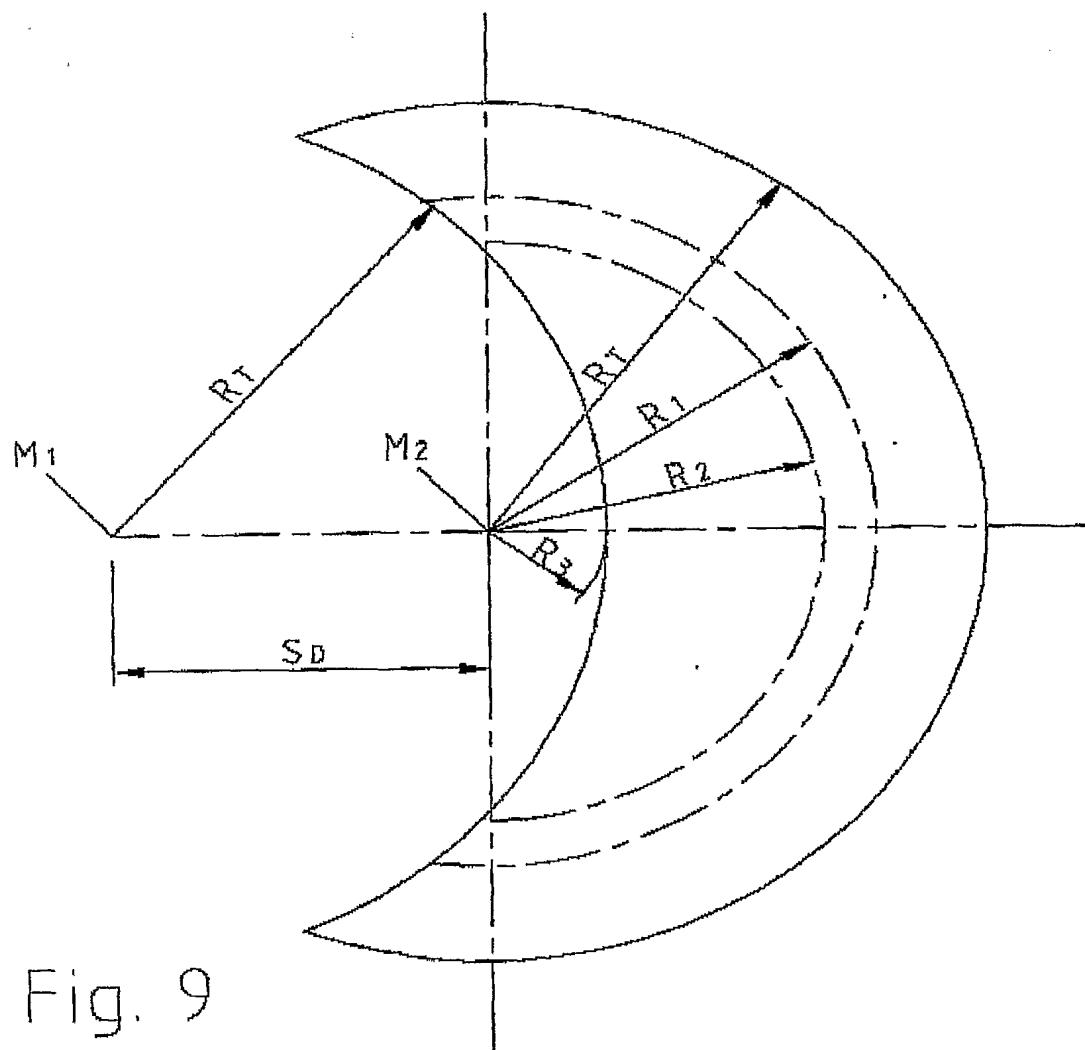


Fig. 9